PB89-181291

Area Sources of VOC (Volatile Organic Compounds) Emissions and Their Contribution to Tropospheric Ozone Concentration

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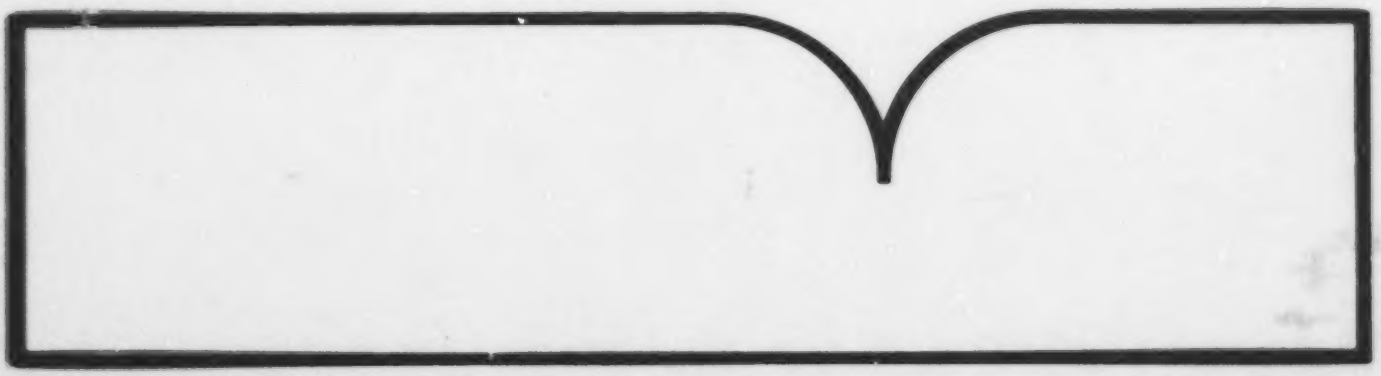
Apr 89



U.S. Department of Commerce
National Technical Information Service
NTIS

EPA/600/D-89/075
April 1989

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Area Sources of VOC Emissions and Their Contribution to Tropospheric Ozone Concentrations

by

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-89/075	2.
3. RECIPIENT'S ACCESSION NO. PB89 181291/AS	
4. TITLE AND SUBTITLE Area Sources of VOC Emissions and Their Contribution to Tropospheric Ozone Concentrations	5. REPORT DATE April 1989
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Michael Kosusko and Sharon L. Nolen	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS See Block 12	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. NA (Inhouse)
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Published paper; 7/88 - 3/89
	14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Michael Kosusko, Mail Drop 62B, 919/541-2734.

16. ABSTRACT The paper quantifies the importance of area sources to total volatile organic compound (VOC) emissions, reviews components of EPA/AEERL's non-attainment program, discusses the status of emission control or prevention for several area sources, and reviews some of the regulatory strategies being implemented or considered by state and local air pollution agencies. In 1988, several projects were undertaken by AEERL to develop a greater understanding of the contribution to the ozone problem by area sources of VOCs. These include studies related to specific sources of VOCs, identification of consumer/commercial product control options, and determination of the regional/seasonal variations in emissions. In each study, available sources of information have been used to develop priorities for the sources of emissions contributing to the ozone non-attainment problem. Sources of data include the technical literature, contacts in industry and elsewhere in the EPA, and surveys conducted by various trade organizations.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Ozone	Stationary Sources	07B
Troposphere	Volatile Organic Compounds	04A
Organic Compounds		07C
Volatility	Area Sources	20M

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 18
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

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INTRODUCTION

The failure of 68 U.S. metropolitan areas to attain the ozone standard by December 31, 1987, was one of the major environmental issues of 1988. Atmospheric chemistry indicates that ozone is the reaction product of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) when mixed in the presence of sunlight. By its regulatory definition, "a 'Volatile Organic Compound' is any organic compound which participates in atmospheric photochemical reactions." The definition of VOC includes any organic compound other than: methane, ethane, 1,1,1-trichloroethylene (methyl chloroform), methylene chloride, and seven chlorofluorocarbons. These are exempt from control because they have negligible photochemical reactivity.[1] Hence, VOC control has been selected as a means of ozone control.

Although substantial emission controls have been placed on many stationary point and mobile sources of VOCs and significant progress has been made, attainment has not occurred in all areas. Many area sources have not yet had any controls applied even though they are known to be a substantial source of VOC emissions. The goals of this paper are to quantify the importance of area sources to the non-attainment problem, review the components of the EPA Air and Energy Engineering Research Laboratory (AEERL) non-attainment research program, discuss the status of emission control or prevention for several area sources, and review some of the regulatory strategies being implemented or considered by state and local air pollution agencies.

In order to understand the importance of area sources to the non-attainment problem, the term area source must be defined. A true area source emission is distributed over a wide area from many small sources which are hard to identify as discrete entities. In recent inventories, a size cutoff [less than 100 tons (90.7 Mg) per year per plant in the 1985 National Acid Precipitation Assessment Program (NAPAP) inventory] has been used to distinguish between area sources and discretely identifiable point sources. Most area sources of VOC consist of small point sources which are too small and too numerous to be inventoried individually at a reasonable cost. These include small point sources such as degreasers, dry cleaning operations, and rubber and plastic manufacturing. In addition, there are several types of widely distributed, very small sources that can be considered as true area sources. These include on- and off-highway vehicles, architectural surface coating, small-scale residential and commercial fuel combustion, and commercial and consumer applications of a wide range of solvent-containing products.

The importance of area sources to the ozone non-attainment problem is highlighted by inventory data recently compiled for use by the Regional Oxidant Model for Northeast Transport (ROMNET) effort. These data indicate that only 10.4% of VOC emissions in the 17 most northeastern states result from point sources, while 35.5% are the result of mobile area sources and 54.1% are emitted from non-mobile area sources. Clearly, area source emissions of VOCs are an important contributor to the non-attainment problem and must be addressed.[2]

AREA SOURCE CATEGORIZATION

In a recent effort sponsored by AEERL, the area source categories from the 1985 National Emissions Data System (NEDS) inventory were ranked for EPA Regions 1, 2, 6, and 9. For each Region, the seven categories with the largest amount of VOC emissions were identified. Preliminary results of this ranking are summarized in Table I. In each of the four Regions, the Evaporative Loss -- Solvents Purchased category was by far the largest non-highway mobile area source category and was of the same order of magnitude as Highway Mobile Sources emissions. Fuel Combustion -- Residential Wood was the second largest category in Regions 1 and 2 (New England, New York, and New Jersey) and significant in Regions 6 (Texas, Arkansas, Louisiana, Oklahoma, and New Mexico) and 9 (California, Arizona, and Nevada, but not Hawaii) on an annual basis. However, summer ozone season emissions from residential wood combustion are expected to be negligible. Other categories showing significant emissions include: Evaporative Loss -- Gasoline Marketed, Gasoline Off-Highway Vehicles, Residential On-site Incineration, Vessels -- Gasoline, Residential -- Open Burning, Cutback Asphalt, and Forest Wildfires.

Because of its magnitude, the solvents category (Evaporative Loss -- Solvents Purchased) was further explored using the 1985 NAPAP area source data. The following NAPAP solvent categories are aggregated under the NEDS Evaporative Loss -- Solvents Purchased category and were included in this review:

Degreasing
Dry Cleaning
Graphic Arts
Rubber and Plastics Manufacturing
Architectural Coating
Auto Body Repair
Paper Coating
Motor Vehicle Manufacturing
Fabricated Metals

Table I. The Seven Largest NEDS Area Source Categories -- 1985

Source Category	REGION 1 Rank	REGION 1 Tons (1000)	REGION 1 % Total Area Source VOC	REGION 2 Rank	REGION 2 Tons (1000)	REGION 2 % Total Area Source VOC
EVAP LOSS - SOLV PURCH	1	317	36.1	1	504	37.1
FUEL COMB - RES WOOD	2	159	18.1	2	199	14.6
EVAP LOSS - GAS MKTD	3	50	5.7	3	86	6.3
GAS OFF HWY VEHICLE	4	27	3.1	4	39	2.9
RES ON-SITE INCIN	5	18	2.1	NA	NA	NA
VESSELS - GASOLINE	6	18	2.1	5	21	1.6
RES - OPEN BURNING	7	14	1.6	6	20	1.5
CUTBACK ASPHALT	NA	NA	NA	7	10	0.7
FOREST WILDFIRES	NA	NA	NA	NA	NA	NA
OTHER NON-HWY		27	3.1		43	3.2
HWY MOBILE SOURCES		247	28.1		436	32.1
TOTAL AREA SOURCES		877	100.0		1358	100.0

Source Category	REGION 6 Rank	REGION 6 Tons (1000)	REGION 6 % Total Area Source VOC	REGION 9 Rank	REGION 9 Tons (1000)	REGION 9 % Total Area Source VOC
EVAP LOSS - SOLV PURCH	1	458	23.8	1	591	29.9
FUEL COMB - RES WOOD	3	130	6.8	3	98	4.9
EVAP LOSS - GAS MKTD	2	136	7.1	2	127	6.4
GAS OFF HWY VEHICLE	5	59	3.1	5	63	3.2
RES ON-SITE INCIN	NA	NA	NA	4	67	3.4
VESSELS - GASOLINE	4	75	3.9	7	33	1.7
RES - OPEN BURNING	7	33	1.7	NA	NA	NA
CUTBACK ASPHALT	6	38	2.0	NA	NA	NA
FOREST WILDFIRES	NA	NA	NA	6	44	2.2
OTHER NON-HWY		167	8.7		166	8.4
HWY MOBILE SOURCES		823	42.9		788	39.9
TOTAL AREA SOURCES		1919	100.0		1977	100.0

NA = Not applicable (i.e., not one of top seven categories)

Machinery Manufacturing
Furniture Manufacturing
Flat Wood Products
Shipbuilding and Repair
Miscellaneous Solvent Use
Miscellaneous Surface Coating
Electrical Equipment Manufacturing
Other Transportation Equipment Manufacturing

Figures 1 to 4 identify the importance of annual VOC emissions from the NAPAP solvent categories in the four Regions. Throughout Regions 1, 2, 6, and 9, the Miscellaneous Solvent Use, Miscellaneous Surface Coating, and Architectural Coating categories consistently rank among the highest emitting categories. The highest emitting manufacturing and coating categories vary from Region to Region reflecting the industrial mix within the states of each Region.

POTENTIAL CONTROL STRATEGIES

Add-on Controls

Point sources are typically controlled by add-on control devices. The control techniques that may be applied to a specific source depend on the emission source and emission characteristics. Although less commonly applied to area sources, add-on controls remain an option if the emissions can be captured by a hood or enclosure or collected by closed vent systems and then transferred to a control device.

Vapor and particulate controls are the two major categories of add-on controls. Vapor controls consist of two types: combustion and recovery. Combustion controls are thermal and catalytic incinerators, flares, and boilers/process heaters. Recovery devices are condensers, absorbers, and adsorbers.[3]

Pollution Prevention

Add-on controls are not technically feasible for all area sources. However, even if technically viable, the high cost of these controls may prove prohibitive for small area sources. In these cases, more innovative approaches may be more appropriate.

EPA has recently begun to investigate the avoidance of generating emissions rather than completely relying on add-on controls. A pollution prevention office has recently been established to help implement pollution prevention concepts in both the regulatory and user communities. In many cases,

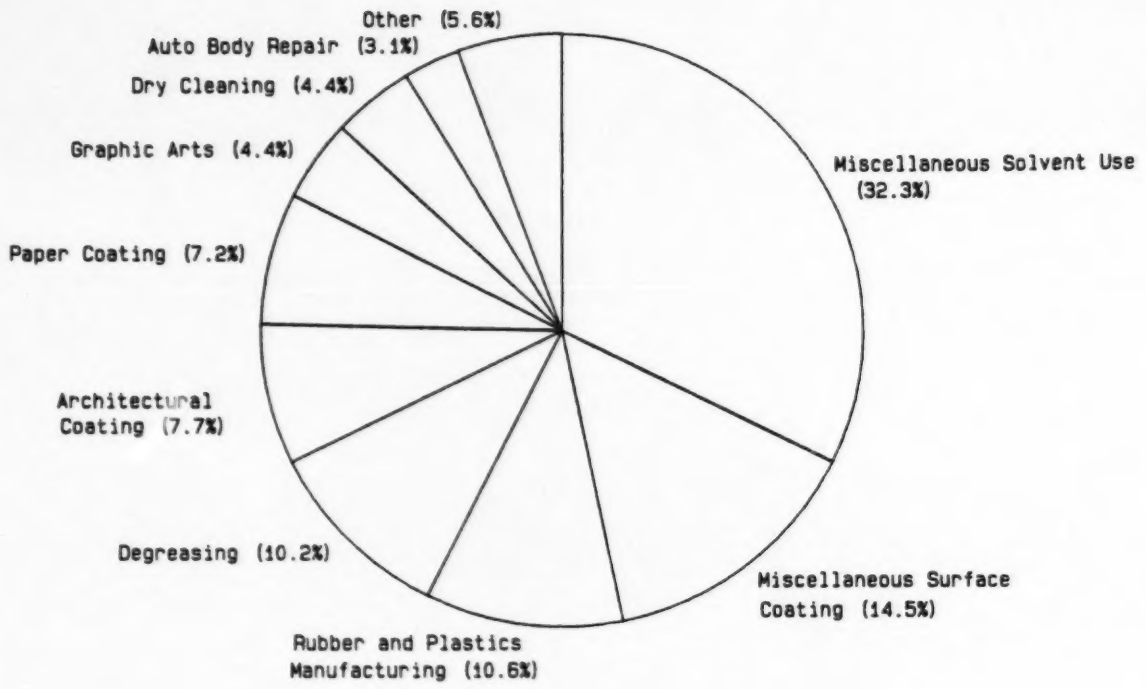

Figure 1. Solvent category emissions -- Region 1.

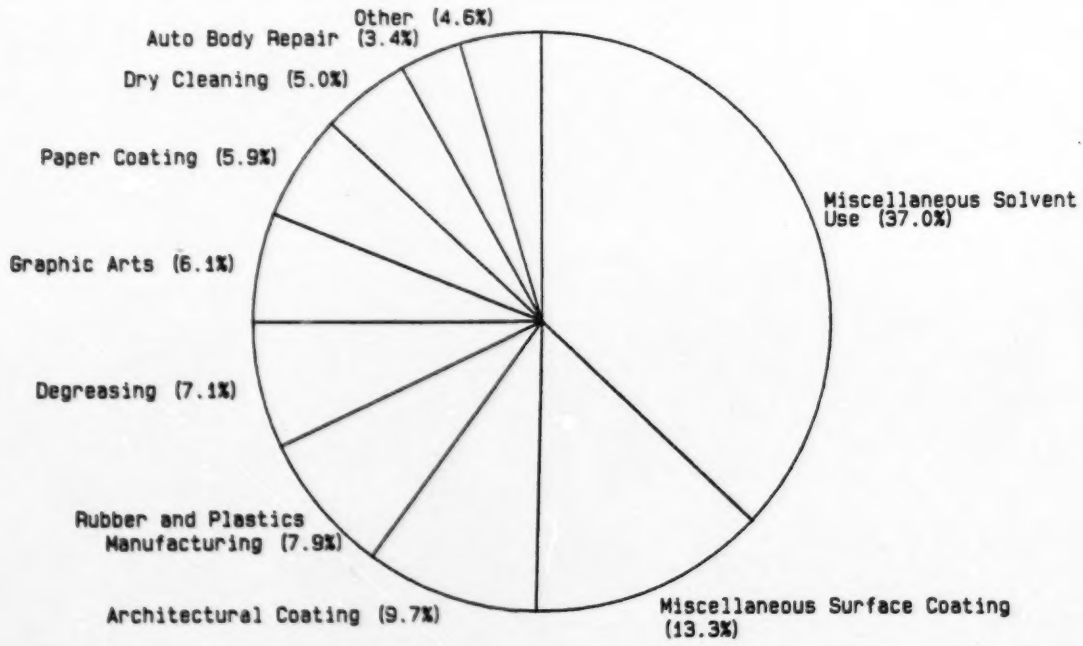

Figure 2. Solvent category emissions -- Region 2.

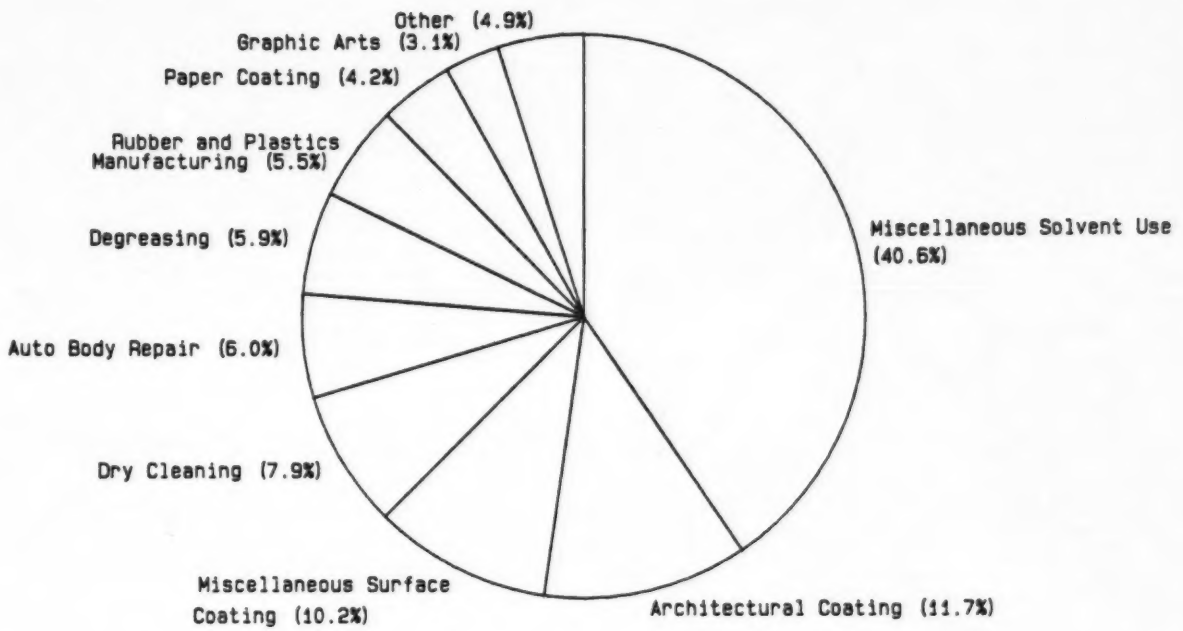

Figure 3. Solvent category emissions -- Region 6.

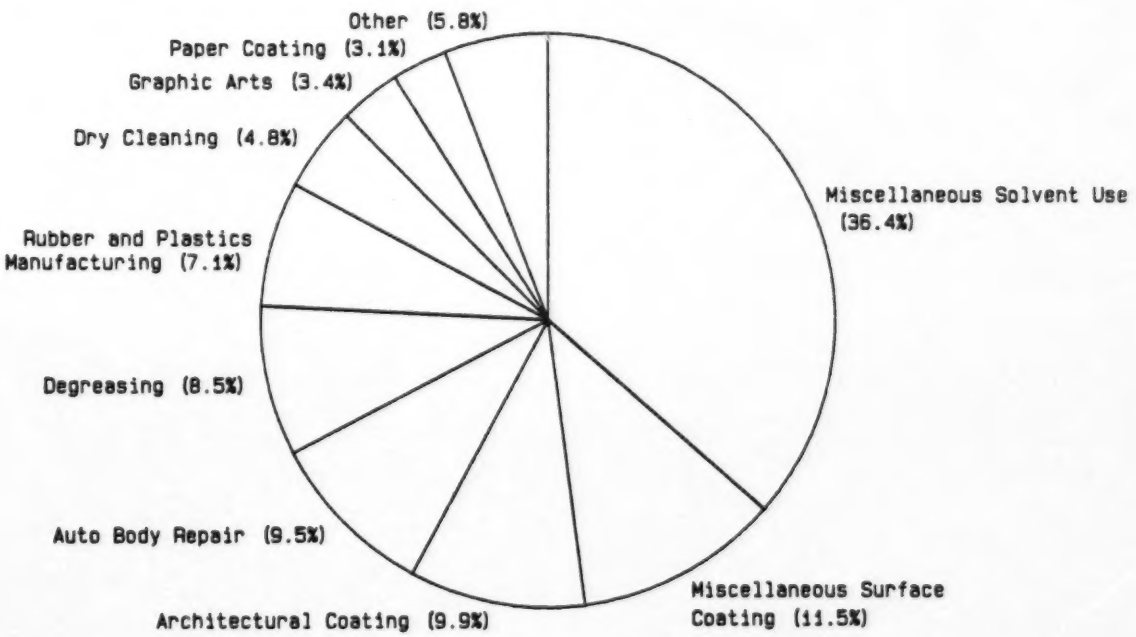

Figure 4. Solvent category emissions -- Region 9.

the more innovative approaches result in a cost savings as well as a positive environmental impact. These approaches will be particularly important in combatting the area source emission problem and are briefly described below.

Process Modification. A process modification results in emissions control at a manufacturing facility via changes in processing which eliminate or change the character of emissions. For example, emissions might be decreased by improved process control which would decrease the number of overpressure vents in a process which result in venting to the atmosphere. Another example is the substitution of electrostatic spray guns for conventional air atomizing spray guns to improve transfer efficiency.

Product Substitution. Substitution refers to the reformulation or the replacement of an existing product. Reformulation refers to the substitution of components into a product which are environmentally less offensive than those they replace. An example of reformulation is the replacement of chlorofluorocarbons (CFCs) with other propellants and solvents in most aerosol products during the 1970s. Replacement refers to the substitution of a different product for a given end use that is environmentally safer than the product currently in use. For example, charcoal lighter fluid can be replaced with the use of electric wands to light charcoal grills.

Product Banning. In some cases environmentally offensive products may have no options for process modification or product substitution. If the product is considered non-essential, banning may be the only option for controlling its emissions.

EXAMPLE AREA SOURCE CATEGORIES

Architectural Coatings

Architectural coatings are paints or other coatings that are applied to structures such as buildings, walls, and bridges. Architectural coatings are generally applied by spray, brush, or roller. Evaporation of solvents present in the coating material during application and drying is the primary source of VOC emissions to the atmosphere from this source. Additional emissions may occur when solvents are used for thinning or cleanup. The geographic distribution of emissions from architectural coating is roughly proportional to population, although other factors (e.g., sales of residential housing, the proportion of rental units, and the types of coatings used) influence the specific level of emissions in a given region.

The ROMNET data base estimates annual emissions of 185,600 tons (168,300 Mg) per year (4.8% of the non-mobile area source inventory).[2] In addition, the Architectural Coatings category was the largest non-aggregated solvent usage category for three of the four Regions (2, 6, and 9) preliminarily reviewed using the 1985 NAPAP inventory data.

Miscellaneous Solvent Use

The Miscellaneous Solvent Use NAPAP category was preliminarily identified to be the largest solvent category in each of the four Regions studied. However, it is a category which consists of many smaller sub-categories which could be industrial, commercial, or residential in nature. AEERL is in the process of identifying and investigating several of the commercial and residential sub-categories. Two of these (consumer/commercial products and aerosols) are described below.

Consumer/Commercial Products. VOC emissions from consumer/commercial products have been estimated to be as much as 6.3 lb (2.9 kg) per person per year.[4] In a large metropolitan area, such as New York, this is equivalent to approximately 100 tons of emissions per day.

During 1988, AEERL commissioned a study to explore the area of consumer/commercial solvent emissions. Existing data sources were evaluated to identify critical consumer/commercial products. State and local agency officials were contacted to determine their current activities and needs. A list of commercial/consumer products that can be controlled to produce a significant impact on VOC emissions was also developed.

In addition to identifying state and local activity, a limited literature search has been completed. The review demonstrates that a data base of some depth on VOC emissions from commercial/consumer products is beginning to be developed. However, there is considerable debate about many elements of this data base, ranging from the reliability of the emission estimates to the effectiveness of controlling emissions from these products in reducing atmospheric levels. Hence, continually updating the data base will provide current information on the critical issues of identifying and quantifying consumer/commercial solvent emissions.

One study identified in the review focused on the top 20 products in the California ranking which were estimated to account for 90% of the total emissions of consumer products in California.[5] The major shortcoming of the available data base is the lack of definitive information on the sales of

products by category and brand name or formulation. In addition, the formulation data presented may not be as current as possible. Some useful observations are nonetheless possible. The first is that the Paints, Primers and Varnishes category has the highest emissions identified in the study. This category has long been recognized as a significant source of VOC emissions, usually under the title of Architectural Coatings, and hence is not inventoried as part of the Miscellaneous Solvent Use category. Other product categories which were found to rank high are hair sprays, room deodorants and disinfectants, and moth control products. All-purpose cleaners, insect sprays, and car polishes and waxes also ranked high enough to be considered in setting priorities. Several categories which ranked in the lower half of the 20 categories are consumer adhesives, lubricants and silicones, engine degreasers, metal cleaners and polishes, and rug and upholstery cleaners.

Aerosols. Propellants used for aerosols prior to 1975 were primarily composed of chlorofluorocarbons (CFCs). During this time, VOCs were primarily used for solvents and active and inert ingredients. The 1978 banning of CFC-11 and CFC-12 for use as propellants in most aerosols resulted in VOCs becoming the primary aerosol propellant. AEERL recently conducted a study into the volatile organic (VO) emissions and uses of aerosol products. Unfortunately, some of EPA's exempted chemicals have not been omitted from the totals. Therefore the numbers presented do not correspond exactly to the Agency's definition of VOCs.[4,6-17]

Aerosols are popular among consumers due to their convenience, neatness, and ease of use. The sealed container also has the advantages of preventing accidental spillage, contamination, evaporation, and dilution. Because of their popularity, aerosol uses range from personal to industrial. The major categories of aerosols and their estimated VO emissions for the U. S. for 1987 are:

CATEGORY	VO EMISSIONS (10^6 lb)
Personal products	390.6
Automotive/industrial products	238.9
Paints and finishes	219.7
Insect sprays	166.3
Household products	148.9
Food products	66.7
Animal products	19.3

where 1 lb equals 0.454 kg.

The percentage of VOs in these products ranges from approximately 100% VO content for hairsprays, insecticides, deodorants, and spot removers to only about 25% for oven and other household cleaners and spray starch. Most similar products have similar VO content.

The number of aerosols produced in the U.S. in 1987 was estimated at 2.7 billion units, an increase of 3.6% over 1986 aerosol production. The overall market has increased by 30% for the last 5 years. Aerosol production increased in 1987 for all of the major categories, except insect sprays. The VOs used in the propellant constitute only about 25% of the VOs used in aerosols. Alternative dispensing mechanisms such as pump sprays have been introduced for many products, lowering the VO content used in the propellant. However, it is unclear whether this really results in a lowering of the VOC emissions due to product reformulation for the different container.

AEERL has gathered available technical information on aerosol products for use by state and local agencies considering regulations on this source. Information was found on aerosol alternatives as well as the use of non-VOC propellants. Of particular interest are products using carbon dioxide (CO_2) as a propellant and the new internal bladder cans. The internal bladder cans use no propellant.

Research is anticipated in several areas related to aerosol products. First, more environmentally safe chemicals could result from work in reformulation. Development of non-VOC, non-CFC products could provide alternatives to current aerosol products. There remains the question of emissions resulting from alternative packaging of products such as pump sprays. Finally, the EPA should continue to work with industry to generate guidelines for identifying chemicals that are the most environmentally safe for use in aerosol products.

REGULATIONS

AEERL's study of area sources has identified a number of state and local agency regulations for these sources. Although the study was not comprehensive and the regulations have not been technically evaluated, a brief summary is presented for information.

Architectural Coatings

A New York Department of Environmental Conservation (NYDEC) rule for architectural coatings limits the VOC content of flat, non-flat, and specialty coatings. The rule

also includes labeling specifications. New York's rule is based largely on existing California regulations for architectural coatings and refinements made by New York's engineering staff.[18] In general, New York tried to develop architectural coating limits similar to California's to avoid conflicting standards between states. However, some differences in coating limits evolved during rule development to meet conditions or concerns unique to New York.

The New York architectural coatings rule applies to coatings manufactured after July 1, 1989.[18] Therefore, enforcement of the rule has not yet begun. CARB has updated their model rule subsequent to the adoption of the NYDEC rule.[19] In the revisions, CARB considered NYDEC's discussions of CARB's earlier rule and some of the problems experienced in California.

Miscellaneous Solvent Use

Several states are actively pursuing the control of consumer/commercial products. As of mid-September 1988, NYDEC finalized its first consumer products rule which covers air fresheners, disinfectants, and pesticides. Affected products are to be registered by September 1, 1989. Comprehensive study protocols to identify alternatives for reducing VOC emissions from these products to the maximum extent feasible are also to be submitted. Alternatives are to be implemented by January 1, 1997. This proposal, covering New York City, Long Island, and parts of Westchester County, is expected to result in emission reductions of 3,000 to 4,000 tons (2,721 to 3,628 Mg) per year.[20]

Meanwhile, NYDEC is studying four additional product types (spray paints, hair sprays, all-purpose cleaners, and adhesives) and recommending potential control strategies for them. It is also reexamining air fresheners, disinfectants, and insecticides, and will concentrate on developing more detailed emission inventory and control strategy information.

The Northeast States for Coordinated Air Use Management (NESCAUM) has become involved with the New York effort and is acting to network state agencies interested in proceeding with consumer solvent regulations. The NESCAUM states, CARB, and the Texas Air Control Board (TACB) have planned the development of guidelines for a number of categories including air fresheners, disinfectants, hair care products, antiperspirants, aerosol spray paints, all-purpose cleaners, consumer adhesives, household insecticides, and (finally) all aerosol cans.

The New Jersey Department of Environmental Protection (NJDEP) published a new rule limiting the amount of volatile organic substances (VOS) in certain architectural coatings and air fresheners on February 21, 1989.[21] For air fresheners, this rule limits VOS content to 50% by weight as of February 28, 1990. This single limit was a revision of the previous proposal, which included further tightening of the VOS limit over time. Previous provisions for consumer insecticides were also reduced to a requirement for record keeping by manufacturers.

Two California agencies, CARB and SCAQMD, are known to be active in consumer product regulations. CARB is driven by the California Clean Air Act - 1988 (Sher Bill),[22] which requires "technically and economically feasible" consumer product regulations to be enacted by January 1, 1992. The Act requires CARB to adopt state regulations for both household and institutional uses of consumer products and to implement statewide enforcement. This is in direct contrast to CARB's earlier role of providing model rules for adoption by the local California agencies. CARB plans to adopt a proposed plan of action during the summer of 1989, which sets the stage for action on consumer products as defined under the Sher Bill.[23] Meanwhile, CARB continues to work on several model rules on architectural coatings, hair spray, underarm products, and laundry products.

SCAQMD is developing rules for transfer efficiency for surface coating, cleanup solvents, record keeping of solvent use, and development of a position on aerosol propellants. Other relevant efforts include a joint effort with a statewide committee on architectural coating, an automobile refinishing rule, and a new rule that will address solvent content of adhesives. In a recent development, SCAQMD approved an Air Quality Management Plan (AQMP) for the Los Angeles area on March 17, 1989. It calls for nearly 120 separate air pollution controls to be implemented through the year 2007 to address Federal requirements. New limits have been imposed on sources as diverse as backyard barbecues, bakeries, and oil refineries.[24]

CONCLUSIONS

Area sources are a significant contributor to VOC emissions and therefore can be assumed to be a contributor to the ozone non-attainment problem. Area sources are generally not regulated or controlled but interest is growing among federal, state, and local agencies. Research to understand and impact VOC emissions from area sources is important at all levels. More and better emission estimates are needed to focus research and regulatory efforts.

FUTURE DIRECTION/PRIORITIES

AEERL, working with the EPA's Office of Air Quality Planning and Standards, has developed its research plans for 1989 based on the information obtained in its study of area sources and summarized in this paper. An effort has been initiated to characterize the consumer products industry. A top-down approach will be taken to understand the industry; document its structure; identify the key players in the marketplace (i.e., large producers of many products and consumer product trade associations); and bring industry and EPA together in several workshops to discuss techniques for reducing VOC emissions from consumer products. We intend to develop an ongoing program to coordinate and assist agencies involved in controlling area source related solvent emissions. Several documents are planned to discuss control options. Topics will cover such sources as architectural coatings, commercial/consumer adhesives, and charcoal lighter fluid. Work on a product substitutes handbook which will discuss pollution prevention options is scheduled to begin in 1990.

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